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M39 VARIABLE RATE/FIRE CONTROL ELECTRONICS

TECHNICAL REPORT

PREPARED BY

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

Design information on the firing circuit by which the firing rate of the M39 20mm automatic gun is controlled is presented. The purpose of the control unit is to separate the variables that have adversely affected successful firing of the M39 gun in the constant recoil mount.

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I. PURPOSE

An electronic circuit by which the firing rate of the M39 20mm automatic gun is controlled from 200spm to 1100spm has been designed and fabricated. The need for this control unit became apparent during the firing tests of the M39 for the constant recoil project. In the initial studies* on the M39, the assumption was that the gun would function in the constant recoil application. However, the gun malfunctioned during controlled firing. Therefore, a rate-controlling firing circuit was designed and fabricated to help determine causes of malfunctions. The design firing rate of the constant recoil application was stated as 600spm. However, because of the operating nature of the gun, this rate could not be initially achieved. This malfunction occurring during constant recoil controlled firing was coined "slide bounce".

The effects of slide bounce were that the gun could be fired at a high natural firing rate of about 1100-1300 spm. However, a discontinuity appeared in the allowable spectrum of firing rates between 300spm and its natural rate of fire.

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*Haug, Edward J., Jr., "A General Constant Force Recoil Mount for Machine Guns in Helicopter Applications," Report OR-68-3, July 1968, US Army Weapons Command, Rock Island, Illinois.

By examination of the capability of the gun to fire throughout the necessary spectrum of firing rates, pertinent performance data apparently can be related to the anticipated success in applications of constant recoil.

This rate-controlled fire control box was needed to examine the merits of the devices used to prevent slide bounce. The antislide bounce mechanisms used are not a subject of this writing; however, a significant amount of firing was done either in attempting to circumvent slide bounce or in preventing slide bounce.

II. DESIGN PHILOSOPHY

A variety of experiences were gained in firing the M39 gun with the initial constant recoil fire control box. The gun was fired early in the tests to determine that the discontinuity in the firing rates between 300spm and its natural firing rate existed. During these early tests the control box was interfaced with outboard circuitry and laboratory instruments. These experiences motivated the design and fabrication of the present self-contained firing unit, easily connected to the gun,and plugged into the range interlocked 117Vac, 60Hz power outlet. (See Figure 1) The high performance low-cost 555 timer integrated-circuit served as the basis for the rate-controlled fire control box. Those supporting components and circuitry to carry out the other necessary functions are described in detail in Section III, CIRCUIT DISCUSSION.

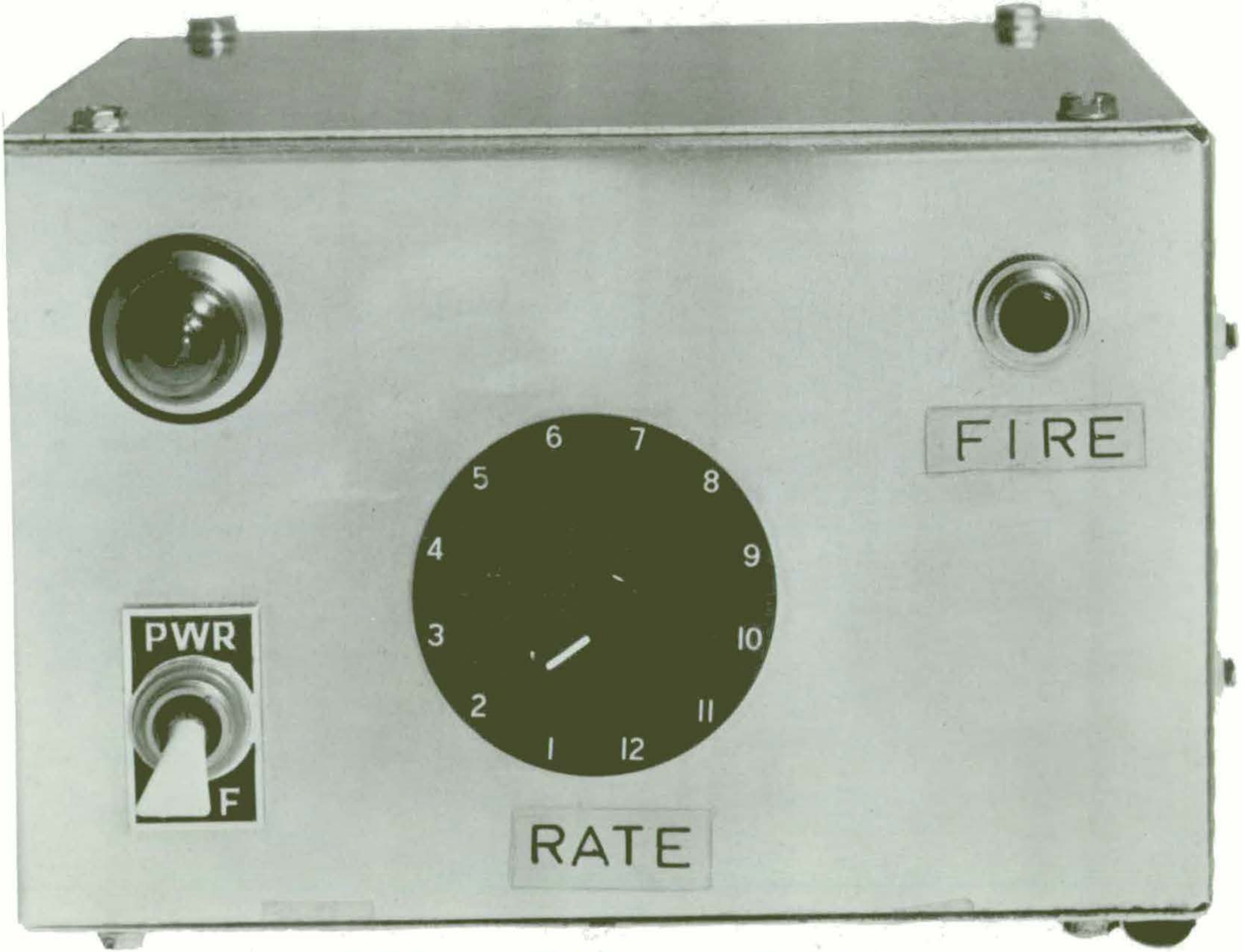


FIGURE 1. - VARIABLE RATE CONTROL BOX

III. CIRCUIT DISCUSSION

The circuit functions are described in the block diagram, Figure 2. The following steps apply:

1. When the firing switch is depressed, two sets of normally open contacts of the firing relay close.

2. One set of contacts initiates astable operation of the 555 timer circuit, the other set of contacts completes the circuit between the negative side of the high voltage supply and slide switch.

3. When the timer circuit reaches its cycle time, the driver circuit triggers the gate of the SCR.

4. The primer is detonated by the 350 volt pulse applied.

5. The firing round opens the slide switch, resetting the SCR.

6. If the firing switch is still depressed, the gun will fire only after another timing pulse is generated by the 555 timer. (This assumes the gun is capable of staying in a ready condition)

The circuit details of the rate controller are shown in Figures 3 and 4. Referring to Figure 3, U1 is an integrated circuit 555 timer. It operates over a wide range of timing intervals requiring only a small number of supporting components. Relay contacts RY1B start the 555 timer into astable operation when the firing push button is depressed. The frequency of operation for the device is

$$f = \frac{1.46}{\left(R5 + R8 + \frac{R6R1}{R6+R7} + 2R9\right)C8} \text{ Hz}$$

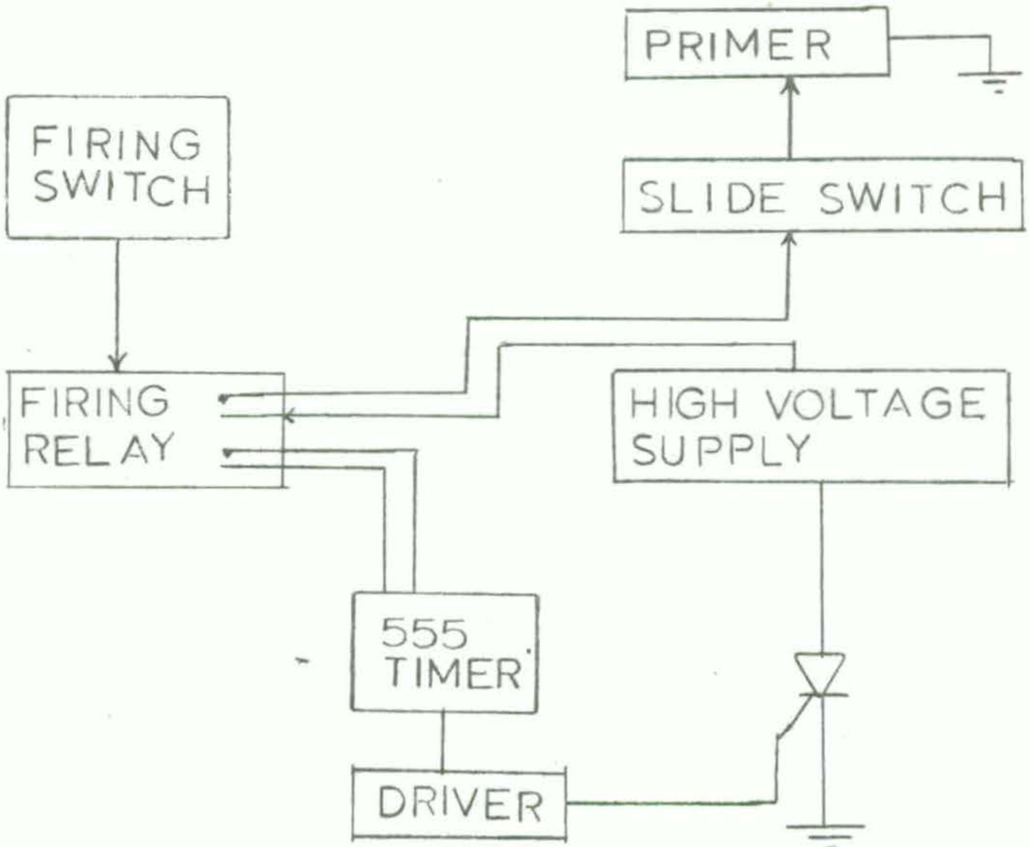
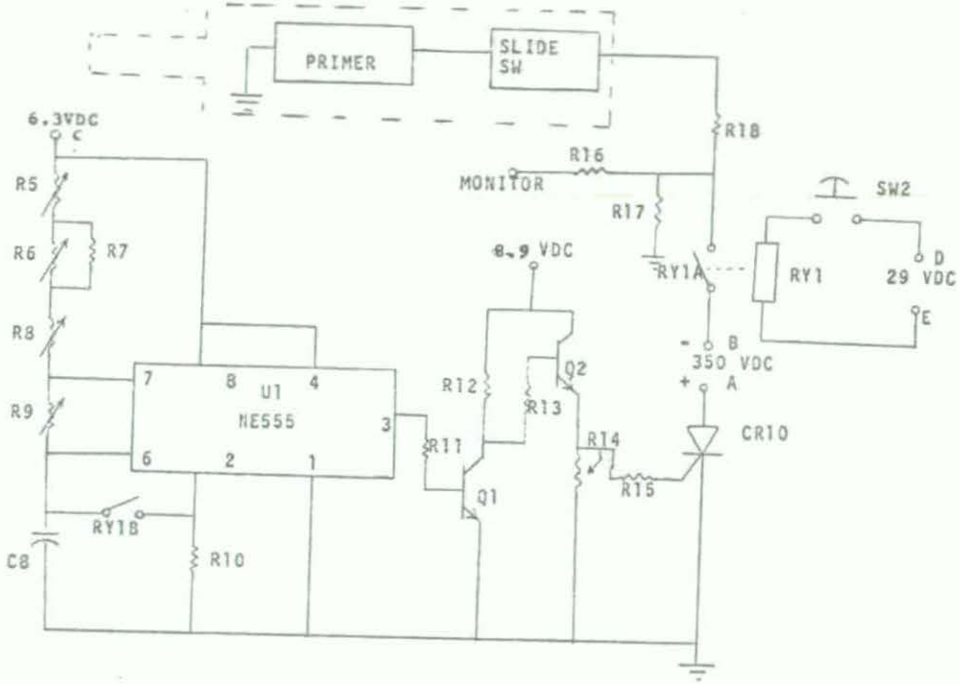


FIGURE 2. - FUNCTIONAL BLOCK DIAGRAM



R5 - 200K ohm Trimpot
R6 - 250K ohm Control Potentiometer
R7 - 150K ohm, 1/2 watt resistor
R8 - 20K ohm Trimpot
R9 - 2K ohm Trimpot
R10 - 150K ohm Trimpot
R11 - 6.8K ohm, 1/2 watt resistor
R12 - 6.8K ohm, 1/2 watt resistor
R13 - 1K ohm, 1/2 watt resistor
R14 - 470 ohm, 1/2 watt resistor
R15 - 270 ohm, 1/2 watt resistor

R16 - 150K ohm, 1/2 watt resistor
R17 - 47K ohm, 1 watt resistor
R18 - 2.5K ohm, 10 watt resistor
C8 - 2 micro farad, 35 volt capacitor
RY1 - Relay
SW2 - Push Button Switch
U1 - NE555 Timer, Integrated circuit
CR10 - C15E, SCR
Q1 - 2N2219 Transistor
Q2 - 2N2219 Transistor

FIGURE 3. - CONTROL CIRCUIT DIAGRAM

The pulse width is given by

$$T1 = 0.685\ R9\ C8.$$

The circuit is set up first by adjustment of a suitable pulse width for triggering the SCR. The value of a few milliseconds was experimentally trimmed.

The range of firing rates was determined by the trimming of resistors R5 and R8 to the fastest desired firing rate while control potentiometer R6 is set at minimum resistance value. This maximum firing rate was chosen to be 1000spm. The lowest firing rate was chosen to be 200spm, a value achieved by the shunting of R7 across control potentiometer R6.

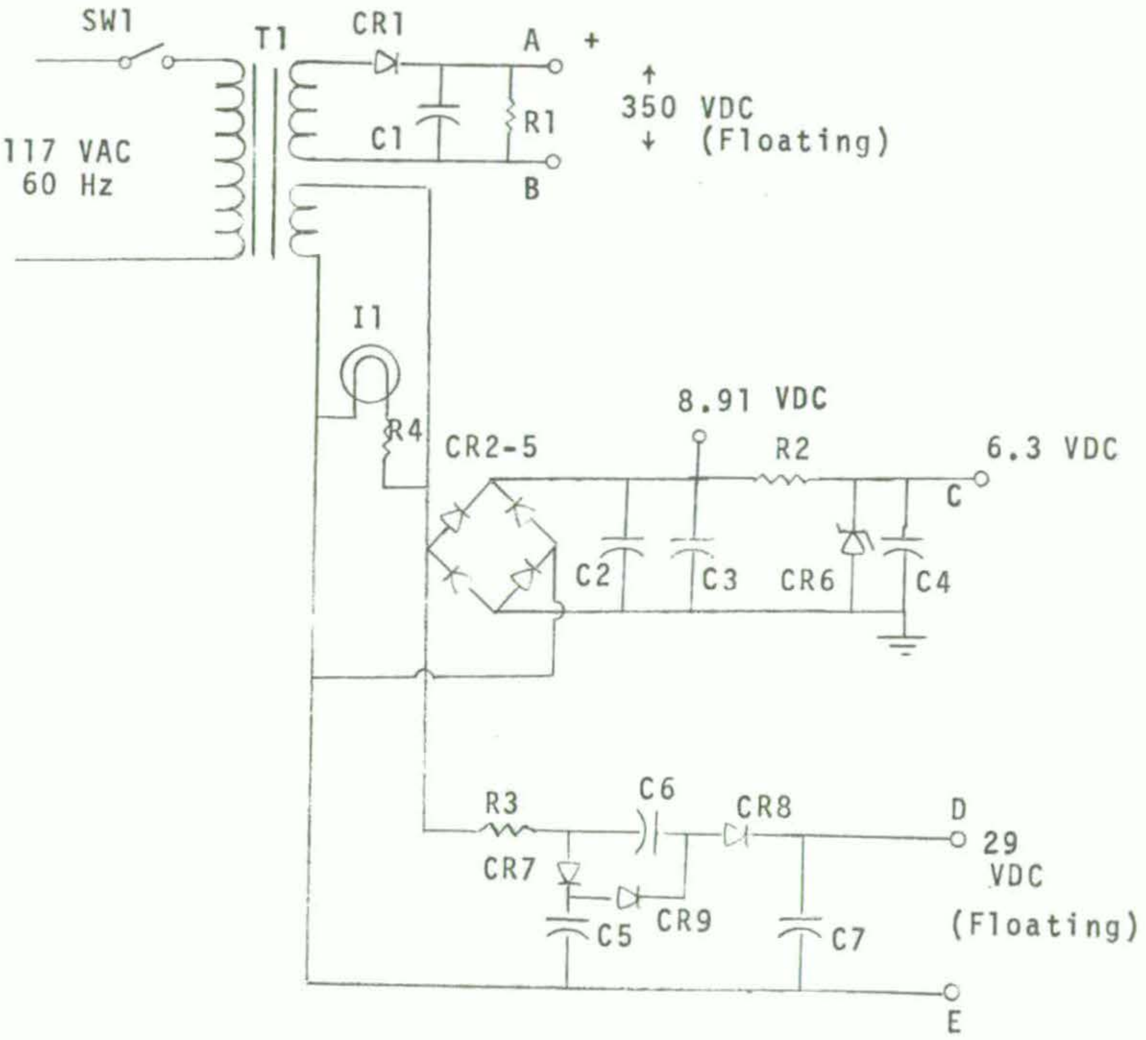
Transistor Q1 inverts the output of the 555 timer. Q1 is direct coupled to transistor Q2, the driver stage to the gate of SCR, CR10. A sensitive gate SCR was avoided. Instead, this SCR was chosen with a 25 ma triggering current to acquire immunity to spurious triggering.

The SCR circuit operates as follows: With the gun in battery, the slide switch closed, and the firing relay closed, the negative supply side of the High Voltage supply is applied to the primer. However, while the timing circuit is timing out, the SCR prevents the positive side of the High Voltage

supply from finding a ground reference. The firing of the primer is prevented until the SCR is triggered. When the timer reaches the end of its timing period, it pulses the gate of the SCR via transistors Q1 and Q2 turning on the SCR. The round fires cycling the gun and opening the slide switch, interrupting the SCR's anode current, resetting the SCR until another timer firing pulse is provided.

Note that resistor R18 and the internal resistance of the High Voltage supply limit the current when shorting occurs. Resistor R16 isolates the firing pulse from monitoring instrumentation. And resistor R17 is an intermediate loading-resistor for the SCR drawing current below the holding current of the SCR.

The schematic diagram of the power supply is shown in Figure 4. The high voltage section is a half wave rectified, filtered supply in which resistor R1 is used to drain off residual voltage when the unit is turned off. This supply is isolated from ground, a requirement previously discussed in the operation of the SCR. Three supply voltages are derived from the 6.3Vac secondary of the transformer. First, a voltage trippler is used to obtain the 29VDC supply for the relay coil. Note that these supply outputs are isolated from the ground reference so that interference with the full-wave



R1, 150 K OHMS
R2, 470 OHMS
R3, 15 OHMS
R4, 2.7 OHMS
C1, 4 MICRO F, 500 V
C2, 200 MICRO F, 35 V
C3, 100 MICRO F, 15 V
C4, 100 MICRO F, 15 V
C5, 50 MICRO F, 50 V
C6, 50 MICRO F, 50 V
C7, 50 MICRO F, 50 V
CR1, 1A, 1000 PRV
CR2-CR5, 1A, 50 PRV
CR6, b.3V, 1 WATT ZENER DIODE
CR7-CR9, 1A, 1000 PRV
I1, NO. 47 LAMP
SW1, TOGGLE SWITCH
T1, 117 VAC PRIMARY
250 VAC @ 25 MA SEC
6.3 VAC @ 1A SEC

FIGURE 4. - POWER SUPPLY CIRCUIT DIAGRAM

does not occur. Second, a full-wave bridge rectified, filtered supply is used to obtain the 8.9VDC supply for the two driver transistors Q1 and Q2. Third, a 6.3Vac zener diode regulated supply is obtained for the 555 timer circuit.

IV. RESULTS AND RECOMMENDATIONS

The M39 gun with antislide bounce attachment was fired through the desired spectrum of firing rates with the use of the variable rate/fire control electronics. Although the gun was rigidly mounted, these firing data gave engineering confidence for firing the gun in the constant recoil mount.

The firing of the M39 gun in the constant recoil mount with the use of the rate control box should be considered. More engineering information should be obtained on the coupling that takes place between the slide forces and the constant recoil mount, on the trade-offs of soft recoil under rate control as opposed to constant recoil, and on the effective mount-force transfer function under different firing rates.

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